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Policies to accelerate the growth of offshore wind energy sector in India

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ABSTRACT

India's power generation capacity needs to be augmented to, support the growing demands for electricity. India, which has predominantly used fossil fuels to power its generators need to make a switch to clean energy fuels. But renewable sources form a miniscule portion (26 GW, ~12%) of India's overall installed power capacity (210 GW). There is no contribution from offshore wind farms to the energy basket for India, as there is no policy framework to encourage the development of offshore wind farms. Several European countries have tapped the offshore wind energy potential to reduce their dependence on adopted by these countries to identify the core components (21 of them) of robust policy intervention. A detailed questionnaire was administered to 181 stakeholders of wind energy in India to seek their feedback on these building blocks. These core components (variables in research parlance) are then subjected to factor analysis to understand the underlying structure of the variables. The factor analysis logically reduces these 21 variables into five factors (Government support, fiscal and quota based incentives, availability of local expertise, capital for investments and building an enabling R&D ecosystem), which are then fed into a logistic regression model as 'independent variables' to predict the probability of growth of offshore wind energy (dependent variable) in the country. The logistic regression model gives the weight (the impact) of these independent variables in influencing the growth of offshore wind energy in India. It emerges that government support, fiscal and quota based incentives and building an enabling R&D ecosystem have a much higher impact on the growth of offshore wind energy for India. This paper fills the gap of absence of an empirically tested framework on offshore wind energy policy for India.

Contents

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1. Introduction

The total power generation capacity in India in December 2012 was 210 GW [1]. Of this, 66.8% was fossil-fuel-fired power plants, 18.6% hydroelectric power, 2.2% nuclear power, and 12.25% renewable energy as shown in Table 1.

India that is experiencing accelerated growth is likely to consume energy more than ever before. However, these rapid enhancements in additional generation capacity need to come, in large proportions, from clean energy sources, as continued dependence on fossil fuel to power its economy will leave a devastated ecology apart from draining the foreign exchange reserves. Increased awareness and regulations around greenhouse gas emissions, environmental concerns and global warming will put additional pressure on India to move away from polluting fossil fuels.

1.1. Projections for power requirement for India

The projections of power requirement for the Indian economy growing at 8% and 9% per annum is given in Table 2 [2]. Taking a comparatively lower figure of 8% growth rate per annum for the next two decades; India needs an installed capacity of over 950,000 MW from the present 210,000 MW—a capacity addition of over 35,000 MW every year for the next 20 years. Of course, the capacity addition figures are much higher, if one considers the economy growth rates of over 9% per annum.

India today produces only 930 billion kW h of electricity and over 400 million Indians (close to 100,000 villages) have no access to grid connected power. India's dependence on the fossil fuels contributes significantly to greenhouse gases emissions. If India failed to protect its environment, not only its economic growth would be impeded but also would pose serious health hazards [3]. Also, the peak power deficit was 38 GW during 2011–12 and the gap in deficit is likely to grow to 64GW by 2016–17 [4]. India imported over 100 million tonnes of coal in 2011/12 [5]. The oil import bill is expected to rise to $150 billion in 2012–13 [6]. With power deficit projected to increase further in the foreseeable future, and traditional fossil fuel based generations straining the foreign exchange reserves, it is expected that India will need additional avenues of power generation to fulfill its energy needs. Hence there is a huge, captive demand for electricity in India and renewable energy can and need to step up to partially fill the deficit in power generation [7].

1.2. Renewable scenario in India

India has access to substantial renewable energy sources – over 300 days of sunshine, steady wind speeds of over 6 m/s and agrarian economy to support bio-fuels – whose potential can be tapped to bridge some of the deficit experienced in power generation and reduce the pressure on the need to commission fossil based power

Table 1
Total installed power generation capacity in India as of 31st December 2012.
Source: CEA, 2013 [1].

Fuel	**MW**	**%**
Total thermal	**140,976**	**66.8**
Coal	120,873	57.29
Gas	18,903	8.96
Oil	1199	0.56
Hydroelectric power	39,339	18.64
Nuclear	4780	2.26
Renewable energy sources	**25856**	12.25
Total	**210,951**	**100.00**

Table 2
Projections for electricity requirement for India.
Source: Ministry of Power, Government of India, 2005 [2].

Year	**Billion kW h**		**Installed capacity (GW)**	
	@8%	**@9%**	**@8%**	**@9%**
2006–07	700	700	140	140
2011–12	1029	1077	206	215
2016–17	1511	1657	303	331
2021–22	2221	2550	445	510
2026–27	3263	3923	655	785
2031–32	4793	6036	**962**	**1207**

Table 3
Achievement of renewable energy sources (in MW) in India, 31st January 2013. .
Source: MNRE, 2013[8]

Renewable energy systems	**Target for 2012–13**	**Achievement during January 2013**	**Cumulative achievement up to 31.01.2013**
Wind power	2500	131.30	18,551.70
Small hydro power	350	10.10	3506.24
Biomass power	455	0	1248.6
Bagasse cogeneration		41.3	2280.93
Waste to power			
—urban	20	0	96.08
—Industrial		0	0
Solar power (SPV)	800	60.23	1236.48
Total	**4125**	**242.93**	**26,920.03**

Nomenclature

AD	Accelerated depreciation
CEA	Central Electricity Authority, India
CERC	Central Electricity Regulatory Commission
EPC	Engineering, Procurement and Construction
EU	European Union
FiT	Feed in tariff
GBI	Generation based incentive
GW	giga watt (=1000 mega watt)
KMO	Kaiser-Meyer-Olkin test
KW	kilo watt
Kw h	kilo-watt hour (1 unit of electricity)
MNRE	Ministry of New and Renewable Energy, Government of India
MW	mega watt (=1000 kilo watt)
REC	Renewable energy certificates
R&D	Research and development
RPO	Renewable purchase obligation
SPSS	Statistical package for the social sciences (Software tool)
TWhr	terra-watt hour (Billion units of power)

plants. Several proactive initiatives from the ministry, research institutions, academia, private investments, thought leaders, financial institutions and project developers have resulted in India installing over 26,000 MW from clean energy sources in the overall power installed capacity of 210,000 MW as of January 2013, which has contributed to India becoming number 5 in the world, in terms of installed wind energy capacity (Table 3) [8].

While, India has tapped most of the renewables sources for generating power, offshore wind energy has remained unexploited as a potential avenue for power generation. India has over 7000 Km of coastline, access to funds, technological knowhow, project management capabilities, economic need, captive market and ecological compulsions to adopt offshore wind energy in an accelerated manner [9].

Today, Europe is a world leader in adoption of offshore wind energy, which was due to several investor friendly policies formulated by individual countries in Europe. India has similar experience of proactive policies driving the growth of onshore wind energy sector in the country. India has to build on the success of its onshore wind energy experiences, while drawing the right lessons from Europe, to grow its offshore wind energy sector.

2. Review of literature

To power its impressive economic growth, India will need to increase its generating capacity to over 300 GW by 2017 [10]. Fossil fuel in the world is limited but most of the electrical energy has been derived from fossil fuel and in the future world will face the fuel crisis [11]. Sooner India moves into a renewables lead energy generation economy; the better it would be for the overall development [12]. Meeting the growing energy demand based on the current pattern of energy supply will become increasingly difficult in view of the needs to keep emissions and crude oil import bill low [13]. One of the reasons for the impressive growth of onshore wind energy is due to the proactive policies adopted by the Government of India [14].

Haas et al. compare different promotion schemes for RES-E world-wide [15]. Huber et al. give a concise summary of different design elements of renewable energy policy instruments for Europe [16]. Van der Linden et al. discuss the success of renewable energy obligation support mechanisms in Europe and in the U.S [17]. Green and Vasilakos compare the policy support that exists for offshore wind energy among a few European countries [18]. Menanteau et al. have shown that a number of renewable energy technologies have benefited, to varying degrees, from support of incentive programs introduced [19]. Toke assesses the effectiveness of the UK's renewable obligation (RO) [20]. Cost reductions and thereby greater adoption for offshore wind energy cannot materialize in the absence of any policy intervention [21]. Boyle mentions that uncertainty of policy environment was one of the deterrents to offshore wind development in the UK [22]. As per Gutermuth the feed-in tariffs in operation in Germany, Denmark and Spain have led to sustained development of wind power [23]. Dinica examines the diffusion of renewable energy technologies and the role of investors [24]. Mitchell compares the UK quota obligation system with the German FIT system for policy effectiveness [25]. Held and Ragwitz analyze the success of policy strategies for the promotion renewable energy sources in the EU [26].

Meyer analyses the major lessons learned from wind energy policy in the EU [27]. Key drivers for the success of wind energy are various policy schemes that promote technology development and diffusion in countries such as Denmark, Germany and the UK [28]. As per Luthi and Prassler wind energy has achieved grid parity in locations with consistently strong winds, its growth has been, due to supportive policies [29]. Esteban et al. gave a detailed comparison between the advantages and disadvantages of onshore and offshore wind farms and concluded that offshore wind farms have immense potential for growth [30]. Toke discusses about how British planning policy on offshore wind is unique vis-a-vis those adopted by other countries in Europe, which helped offshore growth in the UK [31]. Přassler and Schaechtele have shown how policy support instruments determine the financial attractiveness of offshore wind farms in several European countries [32].

Usha Rao and Kishore revealed a strong correlation between the diffusion parameters and the composite policy index for renewable energy sources in India [33]. As per Goyal onshore wind power grew over 27% in India, when dedicated policies for renewable energy were declared [34]. Schmid discusses about the policies that have been effective in the growth of renewable energy power in India in nine states that were identified [35]. Similar views on policies helping to accelerate the growth of onshore wind energy in India have been made by Pillai and Banerjee [36] and Srinivasan S [37]. Hossain et al. have argued that the wind energy potential in India is considerably higher than what was understood till now [38].

It is apparent from existing literature that offshore wind energy sector grew when there were enabling policy environment. However, there is no available literature on what could be the building blocks or basic elements of offshore wind energy policy for India. Also, no model is available for policy makers to empirically test the impact of these policies on the growth of offshore wind energy sector in India. This paper attempts to bridge this research gap.

2.1. Variables found from literature survey

The following superset of variables, as shown in Table 4, was established from the literature survey that formed the building blocks of policy roadmap adopted by these countries [39].

Table 4
Operating definitions of variables identified through literature survey [39].

S no.	Components/Building blocks/Variables
1	**Feed in tariffs (FiT):** Feed in tariff is the rate at which the renewable energy developer will be paid by the utilities/distribution companies for every unit of electricity fed into the grid.
2	**Accelerated depreciation (AD):** Companies that are setting up a renewable energy projects can avail depreciation at higher rates (80% in the case of wind farms) in the first year of operation.
3	**Generation based incentives (GBI):** GBI is a bonus payment given per unit of power injected into the grid to the renewable energy generator, over and above the FiT system.
4	**Legally enforceable RPO/REC:** Renewable purchase obligation (RPO) mandates the distribution utilities to source a pre-decided quantity of electricity, usually a proportion of their supply, from renewable energy sources. Making this RPOs/REC legally enforceable will make it attractive for investors.
5	**Faster approvals/Single window clearance**: Providing single window clearances for setting up offshore wind energy projects will reduce the gestation period for project go-live and also enhance the ease of doing business.
6	**Continuity of policies for long term (more than 10 years):** Continuity of policies for a long term (10 years or more) for predictability and stability in the policy environment.
7	**Adequate evacuation infrastructure to transmit power from high seas:** Availability of and access to transmission infrastructure/grid connectivity from the offshore wind parks to onshore substations.
8	**Tariff determination on wind speeds and not on zones:** Specific tariff rates based on speed of the winds will help development of low wind speeds areas.
9	**Financial incentives like zero import duty, excise duty waiver**: Offering financial incentives like waiver of custom duty, import duties exemptions, tax related schemes for setting up of offshore wind parks.
10	**Availability of expert EPC contractors:** Shortage of skilled resources to install offshore wind farms will invariably delays the commissioning of these farms which then has an impact on cash flows and profitability.
11	**Availability of local manufacturing expertise for wind turbine:** It is relatively inexpensive to source from domestic manufacturers compared to imports and it also reduces the supply chain wait- time dependencies.
12	**Growth of ancillary units (eg Gear box):** Similar to the availability of wind turbines locally, growth of ancillary units that are locally present will accelerate reduction in costs of components thereby increasing adoption.
13	**Superior program execution skills of the developer:** High quality program managers to supervise the installation and commissioning of offshore wind parks.
14	**Accurate data on offshore wind potential sites and wind speeds:** The power output from a wind farm varies directly to the cube of the wind speeds and hence impacts profitability. Hence, accurate data on offshore wind speeds is important to judge the financial attractiveness of the project.
15	**Skills development and training of human resources:** Offshore wind energy project needs 20 people for every MW of capacity installed to manage the project. Skills development and training of these resources is important to ensure smooth functioning of these offshore wind farms.
16	**Active research institutions working on offshore wind energy:** Research institutions that focus on innovation and technology advancement of the offshore wind sector components, research on advances in foundation engineering etc. are vital to accelerate the growth of the offshore sector.
17	**R&D facilities to localize production of expensive equipment:** Growth of R&D facilities that work on finding ways to localize production of all components of offshore wind equipment to reduce the overall costs of offshore wind farms.
18	**'Priority sector' tag to offshore wind energy sector:** Declaring offshore wind as a priority sector will help the sector access funds from banks at attractive rates thereby increasing the attractiveness of the investments in offshore wind projects.
19	**Availability of capital at attractive rates of interest:** If capital is made available at attractive rates, in the absence of priority sector tag - that would help reduce the overall debt servicing burden for the offshore wind energy project developers.
20	**Creation of offshore wind energy fund to reduce cost of capital:** Creation of offshore wind energy fund, using the cess levied on coal and other fossil fuels, and using the accrual to lend to offshore wind energy projects will ease the burden on the developers.
21	**Moratorium on interest payments for the first 5 years of project go-live:** The offshore wind project developers being offered a 5 year moratorium on interest payment after the project goes-live will help in de-risking the investment from the vagaries of learning curve, which is inevitable in any project with large capital investments.

3. Methodology, data analysis and discussions

3.1. Objectives of the study

To develop and empirically test a model of constituents of effective offshore wind energy policy for India.

3.2. Research question

What are the factors that can contribute to the growth of offshore wind energy sector in India?

3.3. Research model

The research model used in the analysis is quantitative model, as the nature of the study and the audience of the study, requires the use of an objective, experimental research model. In this study, data is collected quantitatively using instrument (questionnaire), analyzed using statistical procedures to understand the relationship among the variables to judge the impact of independent variables on the dependent variable. Hence quantitative research model is used in this study.

3.4. Research methodology

As the present research work involved identifying variables of the study, framing of research model, testing of hypotheses, validity and reliability of the instrument apart from extensive use of statistical tools to arrive at the conclusion, quantitative approach to research design and methods was concluded as the appropriate methodology to adopt for this research.

3.5. Sampling

Proportionate stratified sampling was used during the data collection process. The population was divided into different strata (policymakers, academia, wind turbine manufacturers, association members) and number of elements from each stratum, in relation to its proposition in the total population, was selected as shown in Fig. 1. [40]

Sample size—the questionnaire was administered to 240 respondents but some of the responses received were incomplete. So, those who submitted incomplete questionnaire were removed from the list. Finally, *181 respondents* were found to have submitted their responses that were complete in all respects—a response rate of 60% were achieved which is acceptable [41].

3.6. Data collection

Data collection from primary sources was predominantly conducted through structured interview method using a questionnaire. The validity and reliability of the questionnaire was

pre-tested using Cronbach's alpha test and was found to be in compliance with the criteria of $\alpha > 0.7$ [41].

Sources of data—Both primary and secondary data were used for data collection and analysis.

3.7. Model for data analysis

Factor analysis (quantitative method) was used in the study to find out the underlying structure of the variables and also to reduce the set of variables into a smaller set of factors. *Logistic regression* (quantitative method) was used to develop a model that predicts the log-odds of growth of offshore wind energy in India. SPSS V 16.0 software was used for analysis.

The response of the 181 wind energy stakeholders were taken in a 7-point likert scale and were subjected to factor analysis to reduce the 21 variables identified using literature survey into a smaller set of related factors. Kaiser-Meyer-Olkin (KMO) test

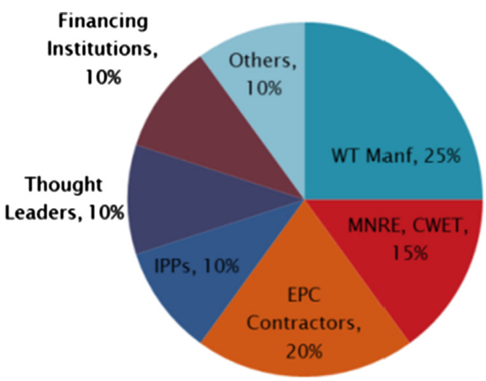

Fig. 1. Break-up of the respondents of the questionnaire.

Table 5
Scores of KMO and Bartlett test.

KMO and Bartlett's test		
Kaiser-Meyer-Olkin (KMO)	Measure of sampling adequacy	0.726
Bartlett test of sphericity	Approx Chi square	3197.603
	df	210
	Sig.	0.000

Table 7
Table showing the variables loading only on one factor.

Variable	Rotated component matrix[a]				
	Component/factors				
	1	2	3	4	5
Faster approvals	0.936				
Policy for longer term	0.915				
Tariff based on wind speeds	0.901				
Grid connectivity	0.821				
Financial incentives	0.777				
Priority sector lending		0.883			
Capital at attractive rates		0.878			
Moratorium on interest payment		0.768			
Offshore wind fund		0.551			
Access to capital		0.528			
Superior program execution			0.857		
Expert EPC contractors			0.836		
Growth of ancillary units			0.770		
Local manufacturing			0.741		
Accelerated depreciation (AD)				0.803	
Generation based incentives (GBI)				0.797	
Feed-in tariff (FiT)				0.668	
Renewable purchase obligation (RPO)				0.580	
Skill development					0.864
Accurate offshore wind speeds					0.827
R&D ecosystem					0.745

Extraction method: principal component analysis.
Rotation method: Varimax with Kaiser normalization.
[a] Rotation converged in 6 iterations.

Table 6
Total variance explained by five factors.

Component	Initial Eigenvalues			Extraction sum of square loadings			Rotation sum of squared loadings		
	Total	% variance	Cumulative %	Total	% variance	Cumulative %	Total	% variance	Cumulative %
1	6.36	30.283	30.283	6.36	30.283	30.283	4.326	20.599	20.599
2	3.182	15.152	45.436	3.182	15.152	45.436	2.935	13.977	34.567
3	2.865	13.644	59.08	2.865	13.644	59.08	2.802	13.344	47.92
4	1.906	9.074	68.154	1.906	9.074	68.154	2.764	13.162	61.082
5	1.124	5.353	73.507	1.124	5.353	73.507	2.609	12.425	73.507
6	0.972	4.63	78.137						
7	0.809	3.85	81.987						
8	0.676	3.22	85.207						
9	0.528	2.515	87.722						
10	0.459	2.185	89.907						
11	0.411	1.957	91.864						
12	0.379	1.805	93.669						
13	0.281	1.337	95.006						
14	0.27	1.285	96.291						
15	0.208	0.992	97.284						
16	0.157	0.747	98.031						
17	0.145	0.69	98.721						
18	0.099	0.472	99.192						
19	0.095	0.451	99.644						
20	0.057	0.27	99.914						
21	0.018	0.086	100						

Extraction method: principal component analysis.

Table 8
Details of the variables that load on various factors.

S. No.	Variables loading on a factor	Factor name
1	1. Faster approvals and single window clearance mechanisms for offshore wind energy projects. 2. Sustainability of policies environment for longer term (10 years or more). 3. Constructing evacuation infrastructure and facilities for storage of electricity not injected into the grid 4. Extending financial incentives like subsidies, moratorium on interest payment, zero duty on imports, excise duty waiver and tax benefits for offshore wind energy projects. 5. Tariff determination on wind speeds and not based on zones.	Government support (Factor 1)
2	1. Availability of capital at attractive rates of interest. 2. Moratorium on interest payments for the first few years of project go-live. 3. Offshore wind energy fund from cess levied on carbon emissions to reduce the cost of capital. 4. Access to funds for offshore wind energy projects. 5. Financial institutions willing to lend to offshore wind projects as priority sector.	Availability of capital for investments (Factor 2)
3	1. Expertise and availability of EPC contractors for commissioning of the wind farms. 2. Manufacture and availability of offshore wind energy components, locally. 3. Growth of ancillary units. 4. Superior program execution skills and capabilities.	Availability of local expertise (Factor 3)
4	1. Feed—in tariff (Higher tariff for offshore wind vis-a-vis other renewable). 2. Accelerated depreciation. 3. Generation based incentives (GBI). 4. Enforcement of renewable purchase obligations (RPO)/Renewable energy certificates (REC).	Fiscal and quota based incentives (Factor 4)
5	1. Research institutions to build accurate data on offshore wind potential sites and wind speeds. (Wind resource map and bathymetric data.) 2. Skills development and training of the human capital on offshore wind systems. 3. R&D to localize production of equipment to reduce costs.	Enabling R&D ecosystem (Factor 5)

Table 9
Case processing summary that shows no missing entry.

Logistic regression [Dataset 1] Case processing summary			
Unweighted cases[a]		***N***	**Percent**
Selected cases	Included in analysis	181	100.0
	Missing cases	0	0
	Total	181	100.0
Unselected cases		0	0
Total		181	100.0
Dependent variable encoding			
Original		**Internal value**	
No growth		0	
Growth		1	

[a] If weight is in effect, see classification table for the total number of cases.

Table 10
Null model with no predictors.

Block 0: Beginning Classification table [a,b]						
Observed			**Predicted**			
			Growth		**Percent correct**	
			0	**1**		
Step 0	Growth	0	0	46	0.0	
		1	0	135	100.0	
	Overall percentage				74.6	
Variables in the equation						
	B	**SE**	**Wald**	**df**	**Sig**	**Exp(B)**
Step 0 Constant	1.077	0.171	39.769	1	0.000	2.935

[a] Constant is included in the model.
[b] The cut value is 0.50.

assesses the adequacy of the correlation among the variables to be eligible for factor analysis. KMO is a measure of sampling adequacy, with a value of 0.5 or higher preferred. In this exercise, KMO output of 0.726, as shown in Table 5, is adequate to proceed with factor analysis [42].

Bartlett test of sphericity is a statistical measure which tests the statistical significance of the inter-correlation among the variables submitted for factor analysis. It verifies the null hypothesis that the variables are independent of each other. If the null hypothesis is accepted it would mean that the variables are independent, and therefore, there is no likelihood of any factor emerging. This null hypothesis of independence of variable should be rejected to conform to the factor analysis assumption that there exists significance correlation among the variables. In this research the Bartlett test of sphericity is significant (as shown in Table 5) which reject the null hypothesis that the variables are independent. This means that the variables are correlated, which is a necessary condition to proceed with factor analysis. Both KMO and Bartlett score give the confidence to proceed with factor analysis [42].

The total variance explained table gives the amount of variance explained by each component after the initial and extraction part of the analysis. In the initial eigenvalue column, 21 components, representing 21 variables, are included.

The total variance explained by all the components (in Table 6) amount to 100% of the variance, first component has the highest (30%) percentage of the total variance in the factor solution. The second component accounts for 15% of the variance, the third component 13.6%, the fourth 9% and the fifth 5.35%. So the five

factors account for close to 75% of the total variation in the 21 variables. The varimax rotation distributes the variations equally across the five factors. The rotated component matrix, Table 7, shows that each variables load significantly on only one factor.

Table 11
Factors 1, 4 & 5 have significant impact on the growth of offshore.

Variables not in the equation					
			Score	df	Sig.
Step 0	Variables	Factor 1	33.03	1	0
		Factor 2	0.313	1	0.576
		Factor 3	0.377	1	0.539
		Factor 4	77.23	1	0
		Factor 5	18.18	1	0
	Overall statistics		129.13	5	0

Table 12
Predictors introduced in the equation have significant impact than constant only model.

Block 1: Method				
Omnibus test of model coefficients				
		Chi-square	**df**	**Sig.**
Step1	Step	167.903	5	0.000
	Block	167.903	5	0.000
	Model	167.903	5	0.000
Model summary				
Step		**−2 Log likelihood**	**Cox and Snell R^2**	**Nagelkerke R^2**
1		37.293[a]	0.605	0.891
Hosmer and Lemeshow test				
Step		**Chi-square**	**df**	**Sig**
1		3.426	8	0.905

[a] Estimation terminated at iteration number 8 because parameter estimates changed by less than 0.001

These five factors that emerged from the analysis are labeled and summarized in Table 8.

Logistic regression is undertaken when there are several independent variables that are metric or categorical while the dependent variable is dichotomous. In the present research, the dependent variable is growth of offshore wind energy (growth/no growth) and the independent variables are the five factors that emerged from factor analysis of the 21 variables identified through literature survey.

The regression model has considered all the entries with no missing cases as shown in Table 9. The first model in the output is a null model, that is, a model with no predictors (Table 10). The constant in the table labeled ‘Variables in the equation’ gives the unconditional log odds of growth (i.e., growth = 1). The Table 11 labeled ‘Variables not in the equation’ gives the results of a score test, also known as a Lagrange multiplier test [43].

The column labeled Score gives the estimated change in model fit if the term is added to the model; the other two columns give the degrees of freedom, and *p*-value (labeled Sig.) for the estimated change. Based on the Table 11, factors 1, 4 and 5 are expected to improve the fit of the model, significantly. The ‘omnibus test of model coefficients’ (Table 12) gives the overall test for the model that includes the predictors. The chi-square value of 167.903 with a *p*-value of less than 0.0005 indicates that the model as a whole fits significantly better than an empty model (i.e., a model with no predictors). Nagelkerke's R^2 of 0.891 indicated a strong relationship between prediction and grouping. Prediction success overall was 96.1% (91.3% for no growth and 97.8% for growth of offshore wind energy).

Hosmer and Lemeshow test (sig of .905) confirms that the model is a very good fit for the data. In the table labeled ‘Variables in the equation’ (Table 13) the coefficients, their standard errors, the wald test statistic with associated degrees of freedom and *p*-values, and the exponentiated coefficient (also known as an odds ratio) are given [43].

Factor 1 (*Government support*), factor 4 (*fiscal and quota based incentives*) and factor 5 (*enabling R&D ecosystem*) are statistically significant. The logistic regression coefficients give the relative impact of the independent variables on the dependent variable (growth of offshore wind energy sector in India).

Table 13
Classification table with predictors included and below gives the ‘b’ coefficients.

Classification table[a]									
Observed				**Predicted**					
				Growth				**Percent correct**	
				0		**1**			
Step 1	Growth	0		42		4		91.3	
		1		3		132		97.8	
	Overall percentage							96.1	
Variables in the equation									
		B	**SE**	**Wald**	**df**	**Sig**	**Exp(B)**	**95% CI for Exp(B)**	
								Lower	**Upper**
Step 1[b]	Factor 1	3.168	0.766	17.117	1	0.000	23.758	5.297	106.555
	Factor 2	0.573	0.580	0.976	1	0.323	1.773	0.569	5.526
	Factor 3	0.340	0.519	0.428	1	0.513	1.405	0.508	3.885
	Factor 4	3.337	0.646	26.653	1	0.000	28.145	7.928	99.918
	Factor 5	2.510	0.842	8.893	1	0.003	12.304	2.364	64.046
	Constant	3.695	0.790	21.850	1	0.000	40.247		

[a] The cut value is 0.500.
[b] Variable(s) entered on step 1: Factor 1, Factor 2, Factor 3, Factor 4, Factor 5.

Logistic regression equation that gives the growth of offshore wind energy in India will be

$$\text{Log}(p/1-p) = 3.695 + 3.168F_1 + 0.573F_2 + 0.340F_{33} + 3.337F_4 + 2.510F_5$$

Government support (F_1), *fiscal and quota based incentives* (F_4) and *enabling R&D ecosystem* (F_5) have high impact on the growth of offshore wind energy in India.

$$\text{Probability of growth of offshore Wind energy in India} = \frac{e\{3.695 + 3.168F_1 + 0.573F_2 + 0.340F_3 + 3.337F_4 + 2.510F_5\}}{1 + e\{3.695 + 3.168F_1 + 0.573F_2 + 0.340F_3 + 3.337F_4 + 2.510F_5\}}$$

Thus, the logistic regression analysis conducted to predict the growth of offshore wind energy in India using Government support, fiscal and quota based incentives, availability of local expertise, enabling R&D ecosystem and availability of capital for investments as predictors shows significant contribution from *Government support*, *fiscal incentives* and *R&D ecosystem* toward the growth of offshore wind energy sector in India. These three levers should be the focus of policy makers in India to proliferate the growth of offshore wind farms in the country.

4. Conclusions

India needs every avenue of energy source to power its economy. Offshore wind energy is an untapped source. The factors that impact the growth of offshore wind energy in India broadly cover *Government support*, *fiscal and quota based incentives*, *availability of local expertise*, *capital for investments and building an enabling R&D ecosystem* (*the various factors that emerged from the analysis*). However, three among the five; *Government support*, *fiscal and quota based incentives and building an enabling R&D ecosystem* have a much higher impact on the growth of offshore wind energy for India and hence needs to be the area of focus.

4.1. Government support

The following variables loaded on the factor called Government support. Policy makers need to focus on

4.1.1. Faster approvals and single window clearance mechanisms for offshore wind energy projects

There are several ministries or departments in India that needs to be approached to obtain consent by the developers of offshore wind energy projects. Such cumbersome procedures will delay the commissioning of these projects, resulting in substantial cost and time overruns, which could not be afforded by developers. Expecting a project developer to obtain these approvals from multiple agencies will be a daunting, show-stopper experience. Hence, it is important to provide a single window clearance for offshore wind energy projects. Similar facilities are available to offshore wind energy developers in Europe, which has significantly benefitted the project developers.

4.1.2. Sustainability of policies environment for longer term (10 years or more)

Policy continuity for long term gives the investors assurance of support from the government for the sector; thereby reducing the risk of future cash flows. Uncertainties in continuation of benefits have slowed down investments in several countries like Netherlands in Europe. Even in India, when accelerated depreciation (AD) for onshore wind energy projects was withdrawn, investments have slowed down. Now project developers in India not only want accelerated depreciation to be re-introduced but also want an assurance from the government that such fiscal benefits will continue for long term; to make further investments in the onshore wind energy sector.

4.1.3. Constructing evacuation Infrastructure from the seas to the land

Several research papers have concluded that availability of evacuation infrastructure is one of the most important criteria for growth of offshore wind energy in any country. Also, transmission infrastructure costs are quite high for offshore wind farms, as sub-sea cabling requires superior engineering skills. Research conducted by independent agencies suggest that investors prefer the Denmark model of, government fully contributing to the building of transmission infrastructure while recovering the costs from the public via a small increase in tariff. Similar model ('Socialising the costs') can be thought of in India, as the capital investments needed for setting up offshore wind energy farms are prohibitive vis-à-vis other renewable energy technologies. So, a project developer will not be able to bear the additional costs of building the evacuation system as well.

4.1.4. Extending financial incentives like subsidies, moratorium on interest payment, zero duty on imports, excise duty waiver and tax benefits for offshore wind energy projects

Offshore wind energy sector in India can be declared as a 'priority sector' by the Government to help developers' access inexpensive bank loans. A priority sector tag, similar to what is given to agriculture, will entail an interest rate of 2% for loans from the banks. Presently, the interest rates are around 12% on the sum advanced for renewable energy projects in the country. As 1 MW of offshore wind farm is likely to cost US$ 3 Million, project developers will find it hard-pressed to service loans at higher rates of interest. Hence, declaring offshore wind as a priority sector will ease a huge amount of burden on project developers and encourage them to take debt on their balance sheets. Cost of capital can also be reduced by levying a cess on fossil fuels and using the sum collected to partly fund offshore wind energy projects in India. Moratorium on interest payments for a period of minimum 5 years was another expectation from the project developers to invest in offshore wind sector in India. Apart from these the Government needs to extend the same benefits given to onshore wind energy sector; to offshore wind sector as well – in terms of zero import duty on equipment and excise duty waivers to kick start the growth of the sector.

4.1.5. Tariff determination on wind speeds and not based on zones

If tariffs are determined on wind speeds – regions with lower wind speeds getting a higher tariff for electricity generated from that area vis-à-vis tariffs from higher wind speed regions – then sites with low wind speeds will also witness investments from project developers, resulting in a secular development of the sector as a whole. Else, one may witness a rush of investments to regions with higher wind speeds and none for those with low wind speeds.

4.2. Fiscal and quota based incentives

The following variables load on the factor called fiscal and quota based incentive. Policy makers need to focus on.

4.2.1. Feed-in tariff (higher TARIFF for offshore wind vis-à-vis other renewable)

All the project developers surveyed for this research have expressed their views that offshore wind energy in India would need a higher incentive (higher Feed-in tariff vis-à-vis other renewable as adopted by Germany), higher renewable obligation

certificates (for example 2 ROCs for every 1 MW h of offshore wind energy as adopted by the UK) at least in the initial few years to be established as another avenue for electricity generation.

4.2.2. Accelerated depreciation

Companies that are setting up a renewable energy projects in India can avail depreciation at higher rates (80% in the case of wind farms) during the first year of operation. This policy has been discontinued recently for onshore wind farms in India, which resulted in reduced flow of investments to the sector. Accelerated depreciation can be re-introduced to promote the growth of offshore wind energy sector in the country.

4.2.3. Generation based incentives (GBI)

GBI is a bonus payment given per KW h of power injected into the grid to the renewable energy generator, over and above the Feed-in-tariff (FiT) system. GBI with a generous cap of (10% the cost of project) over the life of project can be considered.

4.2.4. Enforcement of renewable purchase obligations (RPO)/ renewable energy certificates (REC)

RPO and REC mechanism are market based mechanisms that give superior returns to the project developers, as these certificates are traded in the power exchanges. However, in India these RPO obligations are not mandatory to be met by the distribution companies. So, utilities find ways to circumvent the RPO rules. Enforcement of RPO/REC mechanism will give offshore wind energy project developers the required confidence that their investments are safe.

4.3. Building an enabling R&D ecosystem

The following variables load on the factor called building an enabling R&D ecosystem. Policy makers need to focus on

4.3.1. Research institutions to build accurate data on offshore wind potential sites and wind speeds (Wind resource map and bathymetric data)

India needs research institutions to build bankable data on wind speeds at the seas, to predict the exact potential of offshore wind energy. Wind speeds are very critical to estimate the power output of the offshore wind farms, which decides the cash flows and hence the viability of the project. As the power output varies directly to the cube of the wind speeds, even a minor variation in estimating the wind speeds may results in huge deviation in the power output of the offshore wind farms and hence the cash flows.

4.3.2. Skills development and training of the human capital on offshore wind systems

Offshore wind energy projects generate much needed employment opportunities for the people. Research suggests that offshore wind energy projects can generate an average of 20 jobs per MW including both direct and indirect jobs. Almost 1 million jobs can be created through offshore wind farms in the next few years—assuming a target of 50,000 MW of power generation from offshore wind farms. Indian policy makers need to build the ecosystems of institutions to impart skill training to the people to enable them to be employable in the offshore wind energy sector.

4.3.3. R&D to localize production of expensive equipment to bring the overall costs down

India needs to encourage R&D efforts to accelerate learning, bring down the costs of components, build knowledge base, develop skills in offshore wind farms and localize production of wind turbines. Detailed policies to encourage R&D are needed.

To conclude, five levers were identified that enable the growth of offshore wind energy in India. Out of these five, three levers; *government support*, *fiscal and quota based incentives* and *enabling R&D ecosystem* were recognized as the key components to be supported, as they had the highest impact on the growth of offshore wind energy in the country. However, the other two levers; *availability of local expertise* and *capital for investments* also positively impact the growth of offshore wind energy in the country and hence cannot be ignored. But if the policy makers focus on the three factors and their sub-elements, it will ensure that offshore wind farms takes off in a substantial manner in India. This sector will be an additional power generation avenue for India which has been hitherto untapped. If done judiciously, offshore wind energy will go a long way to satiate the ever growing demand for energy from an emergent India. The core objective of this research was to develop and empirically test a model of constituents of effective offshore wind energy policy for India, apart from identifying the factors that can contribute to the growth of offshore wind energy sector in India. Both these objectives have been discussed in detail in this paper.

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